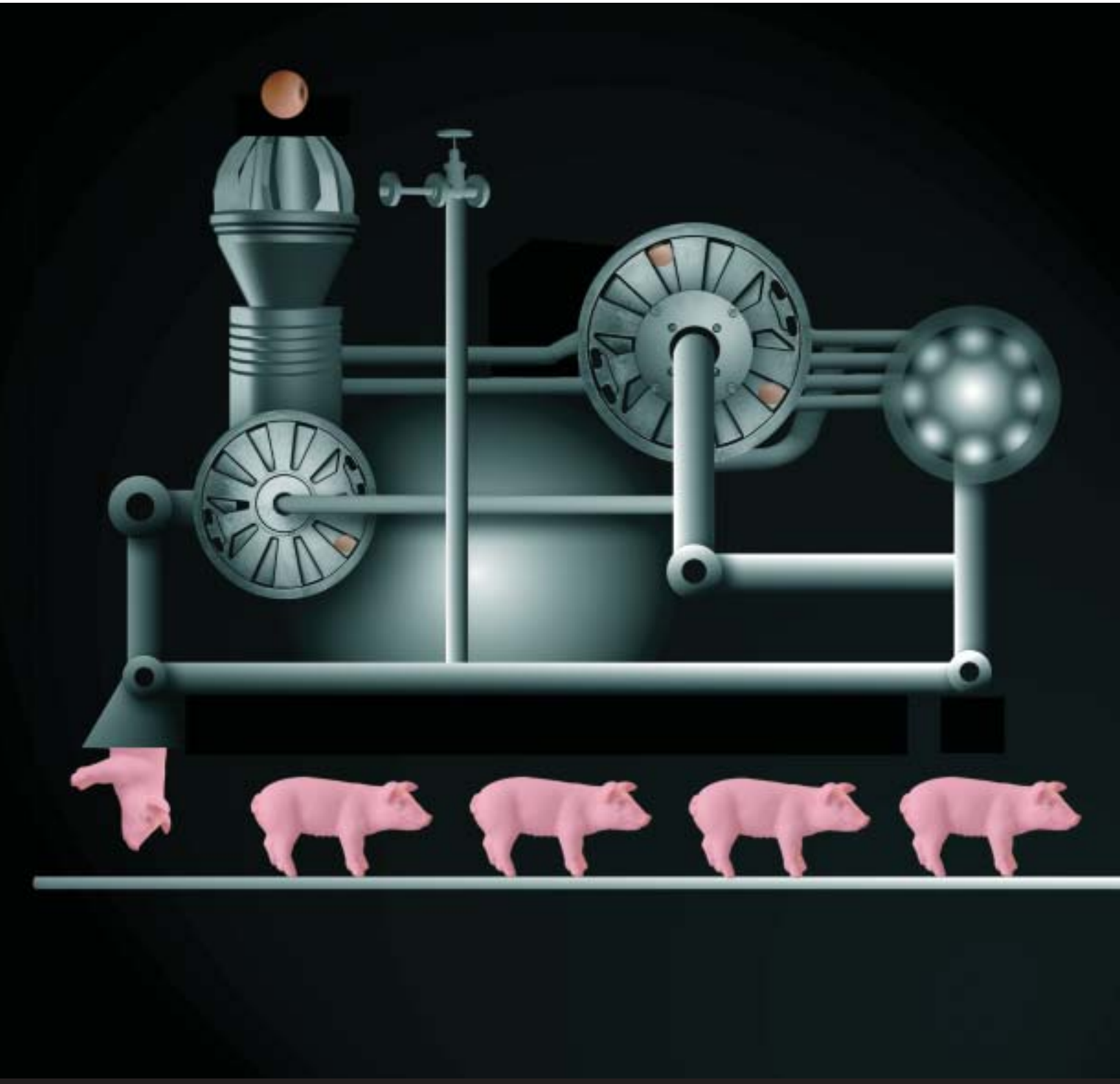
Best use of soy proteins



SOYBEAN PROTEIN IS A VALUABLE RESOURCE, BUT IT IS NOT ALWAYS USED TO BEST EFFECT. DIFFERENT PROCESSING METHODS PRODUCE VARYING QUALITY PRODUCTS. CHOICE AND ASSESSMENT OF SOY PROTEINS FOR FEED APPLICATIONS ARE ESSENTIAL. BY YUEMING DERSJANT-LI AND MANFRED PEISKER.

Soybean products are the primary plant protein source used in animal feed. Restrictions in the use of animal protein have led to an increase in their use. The usage of soybean meal has increased, on average, 5% per year over the past three years.
Many different types of soy products are marketed and used in the feed industry. With their increased use, the importance of protein quality and the methods used to control quality have increased. The quality of soy products is related to the processing technologies employed.

ASSESSING HEAT TREATMENT

Heat treatment is an important step in soy processing. Under-heating will not sufficiently eliminate trypsin inhibitor activity and will reduce protein digestibility. Over-heating, however, will denature proteins and reduce the availability of amino acids.
To evaluate if a soy product has been properly heat processed, the urease index, KOH protein solubility and protein dispersibility index (PDI) are commonly used methods, because these values are easy to measure.
The recommended urease index value is < 0.4 mg N/g.min, indicating properly processed soybean meal. The recommended KOH protein solubility is in the range of 70-85%, used as a measure of properly processed soybean meal and the recommended PDI value is 15-30%. These measurements give indirect indications of trypsin inhibitor activity. The most accurate measurement is to measure the trypsin inhibitor activity directly. However, this requires more time, skill and equipment.
KOH protein solubility and PDI are simple methods sufficient for evaluating protein quality in soybean meal. However, they may not be suitable methods for assessing the protein quality of an alcohol extracted soy protein concentrate, which normally has low PDI or KOH protein solubility, but its low protein solubility is a result of alcohol denaturation of the protein rather than overheating.
It is therefore necessary to clarify the difference in product processing and quality control between soybean meal and alcohol extracted soy protein concentrate.

PROCESSING GIVES DIFFERENT PRODUCTS

The processing method resulting in an alcohol extracted soy protein concentrate and soybean meal is illustrated in *Figure 1*.
The main difference between the processing of soybean meal and soy protein concentrate (SPC) is that for soybean meal the dehulled flakes are drained of excess hexane and passed through a desolventiser/toaster that uses steam to drive off any residual hexane. In the case of soy protein concentrate, the hexane is removed by low heat vacuum drying and the heat treatment occurs after the removal of soluble carbohydrates by ethanol-water extraction. This processing method has the advantage of reducing the Maillard reaction during heat treatment and thu improves the availability of amino acids.

MAILLARD REACTION AND DIGESTIBILITY

Heat treatment of soybeans can reduce the activity of trypsin inhibitors and thereby improve the digestibility of protein. Overheating, however, may destroy or reduce the availability of certain heat sensitive amino acids and reduce the nutritional value of soy protein. When proteins are heated in the presence of certain carbohydrates, the sugars (such as xylose, glucose) can complex with free amino groups, especially the epsilon amino group of lysine. The sugar and amino acids enter into a series of reactions called the Maillard reaction. Consequently, the availability of amino acids is reduced.
As shown in *Figure 1*, the advantage of the SPC production process is the removal of soluble carbohydrates by ethanol extraction before heating. During the heat treatment the occurrence of Maillard reaction is reduced and the digestibility (availability) of amino acids is improved.

NUTRITIONAL IMPLICATIONS

Hancock *et al.* (1990a,b) determined the effect of ethanol extraction and heat treatment of soybean flakes on growth performance, gut function and morphology in piglets (*Table 1*).
Heat treatment after ethanol extraction improved nitrogen digestibility and plasma lysine concentration, particularly in the case of severe heat treatment (i.e. 60

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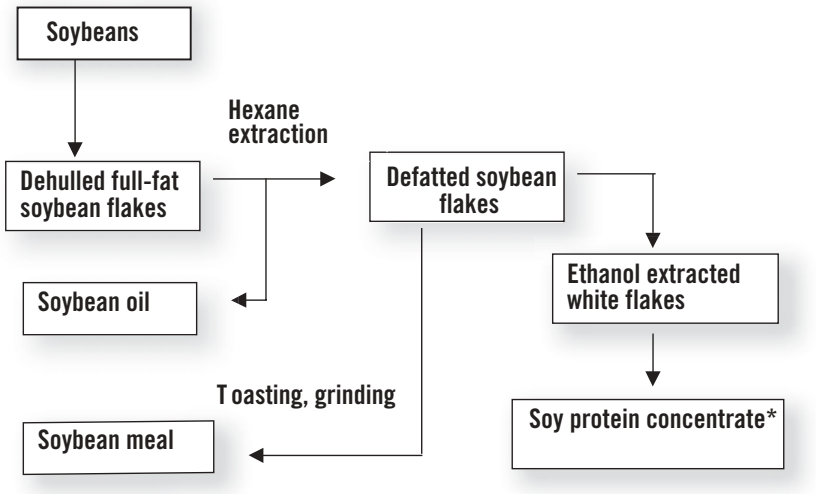
minutes' autoclaving). Ethanol extraction before heat treatment clearly proved beneficial.
Villus height tended to be greater in pigs fed the soybean flakes heated after ethanol extraction and exposed to the intermediate level of heat treatment (*Table 1*). The greater villus height corresponded to improved growth performance. The digestibility of nitrogen and lysine were higher in soy protein produced by heat treatment after ethanol extraction, compared to soybean flakes produced by heat treatment before ethanol extraction. Soy protein produced by ethanol extraction before heating significantly improved feed intake, growth rate and feed utilisation efficiency, demonstrating an improved product quality by this processing method.
Visser and Tolman (1993) also found that soy protein concentrate produced by ethanol extraction had high protein digestibility and supported similar growth performance to milk protein in young calves.
The nutritional composition of soybean meal and soy protein concentrate is compared in *Table 2*, which shows that soy protein concentrate provides a higher concentration of digestible amino acids than soybean meal.

FIGURE 1 - PRODUCTION OF SOY PROTEIN CONCENTRATE AND SOYBEAN MEAL



* Soycomil (ADM Speciality Ingredients, The Netherlands) is a soy protein concentrate specially designed for use in animal feed.

TABLE 1 - PROCESSING SOYBEAN FLAKES AFFECTS PRODUCT COMPOSITION, GROWTH PERFORMANCE AND PHYSIOLOGICAL CHARACTERISTICS IN PIGS (HANCOCK *ET AL.*, 1990A, B)

	Without ethanol extraction			Heat treatment before ethanol extraction			Heat treatment after ethanol extraction		
Minutes of autoclaving	5	20	60	5	20	60	5	20	60
Analysis of the soy product, %:									
Crude protein	50.8	50.9	51.1	65.6	67.1	65.7	66	67.2	66.9
Lysine	3.6	3.6	2.8	4.5	4.5	3.6	4.7	4.6	4.3
Arginine	3.9	4.1	3.5	4.8	5.0	4.5	5.1	5.2	5.1
Histidine	1.3	1.2	1.2	1.6	1.6	1.6	1.7	1.7	1.7
Isoleusine	2.2	2.1	2.2	3	3.1	3.1	3.1	3.2	3.2
Met+cys	2.1	2.0	1.9	2.6	2.7	2.6	2.6	2.6	2.5
Trypsin inhibitor, mg/g	27.8	4.4	0.3	14.5	2.1	0.6	11.2	3.1	0.4
Trial results:									
ADG[1], g/d	65	318	176	188	319	202	227	378	341
ADFI[2], g/d	321	638	461	448	645	511	478	713	711
Gain/feed	0.167	0.499	0.385	0.410	0.493	0.388	0.476	0.533	0.480
Plasma urea, mg/dl	44	39	43	31.8	36.3	45.8	34.5	32.1	39.6
Plasma lysine, %	1.24	1.13	0.69	1.11	1.09	0.92	1.17	1.16	1.32
N digesibility %	72.6	80.9	80	79.6	83.1	80.8	80.7	84.7	82.3
N retention, g/d	5	6	5.1	5.9	6.8	5.3	6.1	6.8	5.9
Duodenum villus height, mm	370	493	461	437	474	379	454	539	520

[1]Average daily gain; [2]Average daily feed intake

PROTEIN SOLUBILITY AND QUALITY

The quality of soybean meal is related to heat treatment- proper heat treatment results in a product with a low trypsin inhibitor activity and high nutritional value. Under or over-heating will reduce the nutritional value of soybean meal products.
Soybean meal quality is normally evaluated by simple tests such as the urease index, KOH protein solubility and protein dispersibility index (PDI). KOH protein solubility is considered as a good method to measure overheating, while PDI is a good method to measure under heating of soybean meal.
Compared to soybean meal, soy protein concentrates produced by ethanol extraction may have lower PDI and KOH protein solubility values. The reason for the low PDI and KOH solubility values differs from that for soybean meal. The ethanol/water extraction (*Figure 1*) denatures the protein, and therefore alcohol washed soy protein concentrate may have a lower PDI and KOH protein solubility value. The molecular changes in the proteins caused by alcohol are, however, different from those resulting from heat denaturation. Thus, alcohol-washed concentrate retains its functional properties despite lower protein solubility as determined by the standard KOH protein solubility or PDI tests.
For soybean meal, it was suggested that KOH protein solubility is a good measure of protein digestibility. However, this may not be the case for soy protein concentrate. Soy protein concentrate may have a lower KOH solubility level but it has a higher amino acid

digestibility compared to properly processed (properly heated) soybean meal (*Table 2*). This indicates that the KOH protein solubility value may not be a good measure of the protein digestibility of the soy protein concentrate, while it is a good method to evaluate the quality of soybean meal.

FEED APPLICATIONS

Feed grade soy protein concentrate has been used successfully as a high quality plant protein ingredient in calf milk replacers, piglets starter feed and pet food.

Calf milk replacers:

Feed grade SPCs, (e.g. Soycomil, ADM Speciality Ingredients, The Netherlands) is characterised by high protein digestibility, low antigen levels, low iron content and high palatability. These make good alternative protein sources to milk protein in milk replacers and have been used commercially for almost three decades in Europe. Using a high quality, low antigen soy protein concentrate as the protein source in milk replacers can help maintain animals' health, enhance growth performance and reduce feed costs as shown by the examples in *Table 3*.

Piglet starter feed:

Feed grade SPC can be used as an alternative protein source to milk protein and fishmeal in piglet starter feed. Using SPC to replace expensive protein ingredients such as skim milk powder can maintain the growth performance of piglets and reduce the feed costs. Compared with fishmeal, soy protein concentrate has the advantage of long shelf life, high concentration of amino acid nitrogen (resulting in low nitrogen excretion), low phosphorous, and a low risk of biogenic amines, dioxin and pathogen contamination.
Using soy protein concentrate to replace low quality, high antigen soybean meal can improve piglets' health status, reduce the incidence of diarrhoea, improve their growth rate and feed utilisation efficiency and thus provide an economic benefit.
Early exposure to low antigen soy protein in young piglet starter feed will allow the piglets to adapt to vegetable protein sources and perform better at a later stage, when plant protein based feed is provided (*Figure 2*).

Pet food:

In pet food, soy protein concentrate is typically used as a partial substitute for meat and meat meal ingredients as a meat extender in dry and canned pet foods. It is an excellent protein source for pet food because it has excellent digestibility and palatability. The components that cause a "beany" taste, are removed during the ethanol/water extraction. Soy protein concentrate contains very low levels of flatulence factors and compared to soybean meal, its use can reduce faecal out-

TABLE 2 - NUTRITIONAL COMPOSITION OF SOY PROTEIN CONCENTRATE* (SPC) AND SOYBEAN MEAL (NRC, 1998)

	SPC*	Soybean meal	SPC*	Soybean meal
Composition % (as is)				
Protein	**65**	**48.5**		
N free extract	**17**	**31.4**		
Water	7	10		
Ash	6	5.8		
Crude fibre	4	3.4		
Fat	1	0.9		
KOH protein solubility, %	79[1]	81.5[2]		
Ileal digestible amino acids (g/100g protein)			**Ileal apparent digestibility (NRC,1998)**	
Lysine	6.05	5.40	93	85
Methionine	1.27	1.21	91	86
Cystine	1.36	1.19	90	77
Threonine	3.78	2.83	90	78
Tryptophan	1.07	1.14	89	80
Leucine	7.44	6.29	93	84
Isoleucine	4.56	3.71	93	84
Valine	4.73	4.26	91	81
Phenylalanine	4.99	4.28	94	85
Anti-nutritional factors				
Trypsin inhibitor (mg/g)	2	1-8		
Glycinin antigen (ppm)	3	66000		
b-conglycinin antigen (ppm)	3	16000		
Lectin (ppm)	<1	10-200		
Oligosaccharides%	2[3]	15		
Saponin	0	0.6		

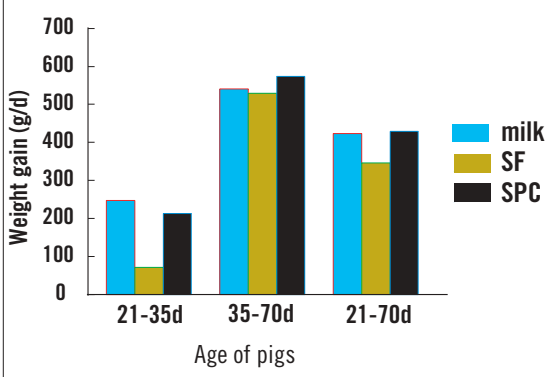
* Soy protein concentrate, Soycomil, ADM Speciality Ingredients, The Netherlands.[1] The KOH protein solubility value of Soycomil R is measured by IFF Institute in Germany. [2] From a report on global soybean meal sampling and analysis activity, average value of 65 samples from different countries. [3] Soycomil contains only 0.6 and 0.04% stachyose and raffinose respectively.

TABLE 3 - SUMMARISED LITERATURE INFORMATION ON THE USE OF SOY PROTEIN CONCENTRATES IN CALF MILK REPLACERS

Soy protein concentrate inclusion level	Performance compared to whole milk protein	Reference
*26.4%	Similar growth rate	Sajko *et al.*, 1998
11.5%	Similar growth rate	Knaus *et al.*, 1994
*10%	No negative effect on meat quality	Bauer, 1991 cited by Knaus *et al.*, 1994
20%	*Similar growth rate*	*Grant et al*, 1989
6%	9% higher weight gain	Morrill *et al.*, 1971
*10%	Increased growth rate	Tolman and Beelen, 1993
*20%	Similar growth rate	Tolman and Beelen, 1993

*Soycomil, ADM Speciality Ingredients, The Netherlands.

FIGURE 2 - THE EFFECT OF DIETARY PROTEIN SOURCES ON THE GROWTH RATE OF PIGLETS. FROM FRIESEN *ET AL.* (1993)*



1. From 21-35 days of age, piglets were fed diets containing dried skimmed milk (milk), soyflake (SF) or soy protein concentrate (SPC) respectively as protein sources.
2. From 35-70 days of age, a corn-soybean meal-based commercial diet was supplied to all groups.
Early exposure to soy protein concentrate clearly had a positive effect on the subsequent growth rate of pigs.

put and improve stool quality (e.g. Clapper *et al.*, 2001; Wiernusz, 1995).

IMPLICATIONS

The KOH protein solubility method is a good measure of protein digestibility for soybean meal, but may not be so effective for alcohol extracted soy protein concentrate. Better quality control criteria for soy protein concentrate are anti-nutritional factors, including trypsin inhibitor activity, antigens, lectins and oligosaccharides. Properly processed soy protein concentrate, specially designed for the feed industry, is characterised by low antigen and other anti-nutritional factors and high amino acid digestibility. Such a soy product is an excellent protein source for calf milk replacers, piglet starter feed and pet food. It provides distinct nutritional advantages that translate into economic benefits. <-

Quality control at a critical stage

Feed grade soy protein concentrate is designed diets for young animals, which are very sensitive to anti-nutritional factors, especially antigens.
The antigens in soy products can cause allergic responses, damage intestinal tissue and increase stress in weaning animals. In practice, diarrhoea is the main disease problem in young animals.
Oligosaccharides cannot be broken down in the digestive system of young animals, which can cause flatulence and diarrhoea.
The quality control criteria for soy protein concentrate should focus on the levels of anti-nutritional factors, including antigen, trypsin inhibitor activity and oligosaccharides.

References

Araba and Dale (1990). *Poultry Science* 69, 1749-1752
Clapper *et al.* (2001). *J. Anim. Sci.* 79, 1523-1532.
Bunge (1997). Bunge Meat Industries Ltd. Report
Endres (1997). Specialty Products Research Notes, SPC-S-17.
Friesen *et al.* (1993). *J. Anim. Sci.* 71, 2089-2098.
Hancock *et al.* (1990a). *J. Anim. Sci.* 68, 3244-3251.
Hancock *et al.* (1990b). *J. Anim. Sci.* 68, 3233-3243.
Grant *et al.* (1989). *J. Nutrition* 119, 1034-1041.
Knaus *et al.* (1994). *Animal Feed Science and Technology* 48, 111-119.
Morrill *et al.* (1971). *J. Dairy Sci.* 54, 1060-1063.
NRC (1998). Nutrient requirements of swine.
Rooke *et al.* (1998). *Animal Feed Science and Technology* 70, 175-190.
Sajko *et al.* (1998). *Acta Academiae Agriculturae ac Technicae Olstenensis, Zootechnica.* 48, 45-54.
Tolman and Beelen (1993). ILOB report no. I 93-3840.
Visser and Tolman (1993). In: Recent Advances of Research in Antinutritional Factors in Legume Seeds. van der Poel, Huisman and Saini (Eds). Wageningen Pers, Wageningen, 447-453.
Wiernusz *et al.* (1995). *Vet. Clin. Nutr.* 2, 49-56.
Zhu *et al.* (1998). AJAS 11, 201-207.